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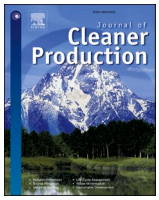

Pre-service teachers' attitudes to and knowledge of marine plastic pollution and its impacts on the natural environment

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ABSTRACT

Marine plastic pollution is a pervasive worldwide problem, with over 17 million metric tons of plastic entering oceans annually. While education is key to addressing this issue, initial teacher education lags behind other types of education. This paper responds to this gap by investigating a small sample of Australian early childhood and primary pre-service teachers' (n = 13) attitudes to and knowledge of marine plastic pollution and its impact on natural environments. A mixed-methods questionnaire revealed that 100% of respondents are concerned about the impacts of marine plastic pollution, 100% believe consumers must demand less plastic, and 91% call for increased government efforts to clean up plastic pollution. Responses to the open-ended questions also identified challenges associated with tackling this issue, including the economic viability and widespread use of plastics, inadequate waste management systems, and resource constraints. Results also revealed that most respondents possess good knowledge about what constitutes marine plastic pollution and the impacts on natural and social systems. However, only a few could identify specific chemical effects of plastic pollution. This study provides baseline data to inform the development of marine plastic pollution education for initial teacher education programs, addressing a critical gap in preparing future teachers to tackle a global issue.

1. Introduction

Marine plastic pollution, also known as marine litter and marine plastic debris (Ahmad-Kamil et al., 2022), is a pervasive worldwide problem. More than 17 million metric tons (Mt) of plastic end up in oceans around the world every year from urban and stormwater runoff, littering and illegal dumping, industrial and construction activities, sewer overflows, inadequate waste disposal and management and tyre abrasion (International Union for Conservation of Nature [IUCN], 2021; United Nations [UN], 2023b). The problem is rapidly intensifying, and it is projected that the volume of marine plastic pollution will double or triple by 2040, and that by 2050 the ocean will contain more plastic, by volume, than fish (Fava, 2022; World Wildlife Fund [WWF], n.d.). The potential for such plastic pollution to impact organisms is a major concern. Plastic materials contain highly toxic additives and chemicals which diffuse into the surrounding environment (Turner, 2016). Plastics take a long time to decompose and, therefore, they can be transported across long distances, ingested, diffuse into surrounding environments, get incorporated into and accumulated in the bodies and tissues of many terrestrial and aquatic organisms (Bradney et al., 2019).

Addressing such an intrusive issue is a global challenge. Education is at the forefront of action, with research indicating that various forms of education (formal, non-formal & informal) can help people understand, minimize and pro-actively manage harm resulting from marine plastic pollution (Ahmad-Kamil et al., 2022; Hartley et al., 2018; Risopoulos-Pichler et al., 2020). The focus of this paper sits in formal initial teacher education, with the working assumption that pre-service teachers are future agents of social influence and change (Ahmad-Kamil et al., 2022; Butera et al., 2021). If pre-service teachers possess a positive attitude and the requisite knowledge and skills to address marine plastic pollution, once in schools, they may be able to positively influence their school community. Comparatively, low levels of knowledge may hinder attitudes and, by default, their competence and confidence to teach others.

Several studies have investigated pre-service teachers' knowledge of environmental issues and their attitudes to the natural environment (Esa, 2010; Taylor et al., 2007; Tuncher et al., 2009). Other studies have focused on knowledge of plastic pollution with in-service teachers (Dalu et al., 2020; Hartley et al., 2018; Martínez-Borreguero et al., 2019), university students (Gan et al., 2022), and school students (Charitou

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et al., 2021; Davison et al., 2021; Locritani et al., 2019; Torres et al., 2019). However, there is limited research to help us understand pre-service teachers' attitudes and knowledge about the specific issue of marine plastic pollution (Boubonari et al., 2013). This paper responds to calls from researchers such as Dalu et al. (2020), Andriopoulou et al. (2022) and Hartley et al. (2018) for studies on pre-service teachers. It does so by investigating a sample of Australian early childhood and primary pre-service teachers' attitudes and knowledge of marine plastic pollution and its impact on natural environments.

The findings provide a baseline for developing marine plastic education for pre-service teachers. An outcome of the research is the development of a preliminary pedagogical framework for the teaching and learning of marine plastic pollution in initial teacher education. Such development is important if initial teacher education is to effectively support the preparation of teachers capable of addressing marine plastic pollution, once in schools. We begin below by explaining the conceptual background and literature underpinning the study, followed by the methods, results, discussion, and conclusions.

2. Conceptual background and literature review

Two bodies of knowledge underpinned this study: Marine plastic pollution and initial teacher education. Every year 19–23 million tons of plastic waste leaks into marine ecosystems, polluting lakes, rivers, and oceans (United Nations Environment Programme, [UNEP], 2023). Arresting the continual spread of plastics requires a concerted policy and educational effort. Working with pre-service teachers aligns with the education effort to empower teachers to be agents of change (Ahmad-Kamil et al., 2022; Hartley et al., 2018; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2016; UN, 2023a).

The study was originally motivated by the first author's own research at Mausund Field Station (www.eider.no), and field-experiences in the remote Froan archipelago in Central Norway. She observed the incursion of vast quantities of macroplastic into the landscape over a decade of research and teaching activities in the area. What was once a pristine, plastic free landscape has been, over decades, invaded with numerous forms of marine plastics including bottles, plastic bags, rope, fishing gear, and other non-identifiable debris of plastic objects. Plastics are carried by ocean currents and winds to the many ponds, small freshwater lakes and terrains of the islands that make up the Froan archipelago (Brandslet, 2022). Over time marine plastics have ended up under the soil and vegetation (Cyvin et al., 2021), leading to concerns about chronic toxicity and damage to organisms living in sediments and the water column in ponds and small freshwater lakes in the Froan archipelago area (Ervik et al., under review).

Plastic pollution is a threat to the health and safety of human and non-human organisms (Campanale et al., 2020; Dissanayake et al., 2022; Turner, 2016) with both physical and chemical effects. Physical harm is caused when plastics accumulate in organisms and lead to internal abrasions and blockages (Wright et al., 2013). For example, in plants, the accumulation of micro-plastics can block cell-walls or cell membranes, restricting transport and absorption of essential nutrients, which can negatively impact root characteristics, growth, and nutrient uptake (Asli and Neumann, 2009). In animals, plastic ingestion is particularly concerning as carcinogenic additive chemicals used in the construction of the plastic are released when they enter the digestive tract (Turner and Filella, 2021; Xu et al., 2020). Over time, the build-up of chemicals can lead to bioaccumulation, which can disrupt cellular processes, promote epigenetic alterations and influence gene expression (Balali-Mood et al., 2021). There are additional concerns about chemicals and microplastics spreading through the food chain (De La Torre, 2020) although the effects of this are not yet known (Davison et al., 2021; Roebroek et al., 2021).

What pre-service teachers learn during their initial teacher education is important. This research is underpinned by the assumption that working with pre-service teachers to develop the necessary knowledge and positive attitudes will support the development of skills to manage and overcome marine plastic pollution and potentially enact broad scale community change. Furthermore, this study is based with pre-service teachers who reside in Far North Queensland, Australia, which is home to the Great Barrier Reef (GBR). Based on the great deal of attention given to the GBR by the media (including traditional books, magazines, television, radio & social media), politicians, policy makers, environmental organisations, and local education bodies, it stands to reason that the pre-service teachers in our sample are aware of and may have observed the impact of marine plastic pollution on this world heritage site. Research shows that life experiences of pre-service teachers play an important role in pro-environmental behavior as well as the commitment to teach about environmental issues (Kennelly et al., 2008; Shuman and Ham, 1997). Additionally, development of pedagogical content knowledge and skills to effectively deliver marine litter education can reinforce pre-service teachers' determination to teach about this issue. However, the inclusion of marine plastic pollution in initial teacher education is an emergent area of research and the extent to which pre-service teachers learn and know about plastic pollution is still uncertain. One study by Boubonari et al. (2013) on Greek primary school pre-service teachers, found that they possess relatively moderate levels of knowledge about marine pollution and hold many misconceptions. Another study by Martínez-Borreguero et al. (2019), based on the similar subject of waste with Spanish secondary pre-service teachers, concluded that they have basic knowledge. Such findings are reflected in studies with practicing teachers, albeit research is also in the developmental stages. Dalu et al. (2020), working with South African teachers, found most have low levels of awareness and knowledge of plastic pollution.

Studies with university students and marine plastic pollution, although also limited, reflect quite different findings. Gan et al. (2022) found Chinese university students have good knowledge of marine plastic pollution. Raab and Bogner (2021), working with German university students, reported variable levels of knowledge. Students could identify conventional plastic products such as plastic bags and bottles, classify microplastics as small plastics, were aware of their different origins and perceived them as dangerous. However, only a few students were aware that items such as textiles and detergents contain plastic fibers. In Taiwan, Situmorang et al. (2020) investigating the correlation between students' knowledge and behaviors related to plastics, found that students with higher levels of knowledge about the negative impact of plastic waste, were more likely to engage in actions to reduce plastic usage, including re-using plastic containers and taking their own bags to shop. Overall, in line with Mironenko and Mironenko (2022), who reviewed plastic pollution initiatives taken up by universities, it appears that plastic pollution education is increasingly being taken up across a range of programs but is still a long way off being an inherent part of tertiary-level courses.

In summary, our review of the literature highlights the insidious and threatening nature of plastic pollution, that knowledge about plastic amongst university students is variable, develops over time and can lead to positive actions. This led us to the research question: What are pre-service teachers' attitudes to and knowledge of marine plastic pollution and its impacts on natural environments? Drawing from established research such as Ajzen et al. (2011) and de Leeuw et al. (2015), we recognize that knowledge alone does not translate into action. However, when combined with positive attitudes, it can influence behavioural intentions. Hence, we contend that examining pre-service teachers' attitudes and knowledge will establish a baseline for developing targeted interventions capable of better preparing future teachers who can influence positive change for marine plastic pollution.

3. Methods

3.1. Research context

The pre-service teachers in this study's sample were enrolled in a Bachelor of Education: Early Childhood or Primary. The programs mostly attract local students who reside in the GBR catchment area and have firsthand personal experiences of the beauty and significance of such local World Heritage areas and are aware of the visible marine plastic pollution that lies within catchment areas. They also have first-hand educational experiences at school through initiatives such as the widespread Reef Guardian School's program (Australia Government, Great Barrier Reef Marine Park Authority [GBRMPA], 2021) that teaches students about reef health, biodiversity, sustainability, and threats such as marine debris. Further, in their first year of study, they undertake a science and sustainability education subject where they learn about marine plastic pollution, particularly in relation to the GBR.

3.2. Research approach

The research is underpinned by a pragmatist worldview (Creswell, 2014) which suggests that researchers use a range of methods to derive a comprehensive understanding of the research problem (Tashakkori and Teddlie, 2010). Therefore, both quantitative and qualitative methods were utilized in addressing the research question outlined above. A qualitative approach involving open-ended questions were used to elicit student teachers' knowledge of marine plastic pollution and its impacts on natural environments, while a quantitative questionnaire was used to investigate their attitudes towards this issue. The data collection instrument and its development are described next.

3.3. Data collection instrument

The questionnaire was made up of three sections (A, B, C) with a total of 14 questions (Appendix A). In order to be able to assess pre-service teachers' more nuanced attitudes to marine plastic pollution, the survey was designed with the first four questions (Q1-Q4) formulated as statements and the answers to be ticked on the Likert-type items. The Likert-type items were divided into five response options ranging from strongly agree to strongly disagree, including a neutral choice, and justified their statement of Q4 in Q5.

Q6-Q14 were open-ended questions. Q6-Q9 were formulated to gather information about the informants' knowledge of plastics and the challenges of marine plastic pollution, and Q10-Q14 were formulated to investigate pre-service teachers' knowledge of the impacts of marine plastic pollution on the natural environment. The purpose of these open-ended questions was to delve more deeply into pre-service teachers' knowledge regarding the issue of marine plastic pollution and its impacts on natural systems.

The questionnaire was adapted from Boubonari et al. (2013) and Ahmad-Kamil et al.'s (2022) work. Boubonari et al. (2013) designed a questionnaire to assess Greek primary pre-service teachers' knowledge, attitudes, and self-reported behavior towards marine pollution. Ahmad-Kamil et al. (2022) applied a scoping review method to discern what knowledge and understanding are necessary for teachers to effectively implement marine litter education. Outcomes from the above study highlighted seven categories of content knowledge required for teachers to effectively teach marine litter education: Marine litter, monitoring marine litter, microplastics, marine biodiversity, littering, marine ecosystem, and teaching Environmental Education (EE)/Education for Sustainable Development (ESD). The adaptations to the questionnaire included the addition of demographic questions related to gender, age, highest education level attained, and qualification being sought. Open-ended questions that drew from four of Ahmad-Kamil and colleagues' (2022) seven content knowledge categories: marine litter, microplastics, marine biodiversity, and marine ecosystem were also added to assess pre-service teachers' knowledge of marine plastic pollution and its impacts on natural systems. To validate the questionnaire and ensure clarity and readability, the questions were reviewed by a colleague and the University's Human Research Ethics Committee. Feedback from both led to minor modifications to wording and item sequence.

Data was collected from February to June 2023 (semester 1) via an anonymous online questionnaire hosted on the Qualtrics survey platform. Ethical approval was gained from the Human Research Ethics Committee at James Cook University (JCU), Australia: Approval number: H8982. An invitation to participate in the research was emailed to all pre-service teachers enrolled in the science and sustainability subject. Of 80 pre-service teachers enrolled, 13 consented to participate and completed the questionnaire (Table 1).

3.4. Data analysis

Eleven out of 13 students responded to the Likert-type items (Q1-Q4). Percentage of responses in each category (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) was calculated (Appendix B). This is because the data from the Likert-type items are considered ordinal and calculation of percentage of response in each category is more appropriate for this type of data (Blaikie, 2003; Jamieson, 2004).

Analysis of the responses to the open-ended questions was informed by the research question and Braun and Clarke's (2021) thematic analysis. This involved the first author reading the responses from the 13 participants to identify inherent terms (as per Table 2) then using these to develop 98 codes (Table 3). Member checking followed (Birt et al., 2016) and involved the second and third authors independently checking the codes. After this initial coding, the first author then clustered codes that had a mutual thematic connection into 34 sub-themes (Table 3). Discussion between all authors followed to interrogate the 34 sub-themes. Any discrepancies and inconsistencies were resolved through discussion between the three authors. For ease of reporting, the authors then consolidated the sub-themes into three final themes which represented the main ideas in the research question:

1. Attitudes to marine plastic pollution
2. Knowledge of marine plastic pollution
3. Knowledge of the impact of marine plastic pollution on natural systems

Theme 1 was related to Q5, theme 2 was related to Q6-Q9, and theme 3 was related to Q10-Q14.

Table 2 illustrates the coding process using question 10 as an example (What are the consequences of marine plastic pollution on nature?), showing how the answers were marked and numbered in codes (columns 1 and 2), and clustered into sub themes (column 3). Finally, similar sub themes were consolidated into the themes (column 4):

- knowledge about what marine plastic pollution is.
- knowledge about the impact of marine plastic pollution on natural systems.

4. Results

The results presented in the three subsections 4.1-4.3, are based on three Themes: 1) attitudes to marine plastic pollution, 2) knowledge of marine plastic pollution and 3) knowledge of the impact of marine

Table 1
Details of study participants.

Males	Females	Age range	Early childhood	Primary school teaching
1	12	18–39	1	12

Table 2
Example coding process.

1	2	3	4
Q10	Codes	Sub themes	Themes
Answer 1: It is toxic, can kill marine life, disrupt the food chain. This in turn can disrupt a whole eco system, reducing fishing (food) and tourism. Answer 2: Marine life can ingest or become caught in plastic pollution that causes harm/illness/death. Microplastic when ingested can cause long term health issues (more research needed into extent of this). Toxin released from the plastic pollution cause harm/damage and negative effects on marine life and ecosystems	Kill marine life (54) Disrupt the food chain (56). Disrupt the ecosystem (59) Reducing fishing and tourism (62) Ingesting (55) Caught (58) Health issues (61) Toxin released affect marine life (63)	Ingesting and released toxins kill marine organism (23) Disrupt the food chain, ecosystem and can cause health issues (24) Reducing fishing and tourism (26)	Knowledge of marine plastic pollution Knowledge of the impact of marine plastic pollution on natural systems

plastic pollution on natural systems. For each theme, sub-themes and wording from individual responses (before it was coded) provide additional information about pre-service teachers' attitudes to and knowledge about marine plastic pollution, and the impact of marine plastic pollution on the natural systems.

4.1. Pre-service teachers' attitudes to marine plastic pollution

The results from the quantitative data comprising the Likert scale items (Q1-4) are presented in Appendix B. 100% of the students agreed that we should be concerned about high levels of marine plastic pollution. They also agreed that consumers must demand less plastic to reduce plastic production (100%). Additionally, 91% of students strongly agreed or agreed that the government should increase efforts to clean up marine plastic pollution, even if it means spending more money.

What emerged from the qualitative data was a concern regarding the impacts of marine plastic pollution. Responses to question 5 provided a range of reasons for why we should be concerned about high levels of marine plastic pollution, including that marine plastic pollution:

- negatively impacts the health of organisms, ecosystems, and marine habitats, and these are essential for human survival;
- adds to already large volumes of pollution;
- increases extinction rates;
- creates water pollution;
- hinders opportunities for children to experience the GBR in the future;
- specifically micro-plastics (as a form of marine plastic pollution) negatively impact humans who eat seafood.

The reasons for concern that were identified in this study may reflect the participants' personal experience of the impact of marine plastic pollution on the GBR as indicated by one of the participant's comments:

> I agree that we need to be concerned about the high levels of marine plastic pollution because in the future I would want my children to still be able to go to the Barrier Reef [GBR] just as I have.

However, concern about marine plastic pollution was also expressed at a global level, although with an anthropocentric viewpoint: "Marine plastics pose a significant threat to biodiversity in ecosystems and the environment globally. Plus, balanced marine habitats are essential to human survival".

4.2. Pre-service teachers' knowledge about marine plastic pollution

Responses to open-ended questions 6 to 9 (46% answered Q6-Q8; 31% answered Q9) provided insight into pre-service teachers' knowledge of what marine plastic pollution is. Pre-service teachers' responses indicated that they:

- believed that human activities caused marine plastic pollution;
- knew that plastic in the ocean includes plastic debris and microplastic;
- knew that marine plastic had negative impacts on marine life and marine ecosystems;
- knew that marine plastic pollution is found in waterways and waterbodies, beaches, and in marine organisms;
- recognized that ultraviolet radiation caused weathering of marine plastic, breaking it down to microplastic. During this process, chemicals that were toxic to marine life were released into the water and accumulated in the environment.

Pre-service teachers also identified some challenges associated with tackling marine plastic pollution. These included:

- the fact that plastic is cheap and widely used, thereby making it difficult to reduce production and consumption;
- the recognition that wastes management practices are inadequate;
- the recognition that there are economic costs involved in cleaning up microplastics and lack of resources exacerbate this problem.

The participant responses indicate that pre-service teachers had good knowledge of marine plastic pollution and may reflect the instruction that they receive in their course during their first year of study, particularly in relation to the GBR. The responses provided a succinct description of the main challenges associated with tackling this issue: "It is convenient to use and cheap to make … plastic is a very convenient solution to modern life".

On the other hand, some uncertainty was expressed by the pre-service teachers regarding the difference between plastic that has been lying in nature for a long time and newly produced plastic: "I'm not sure about the chemical structure, I know marine plastics slowly breakdown physically to micro plastics that are impossible to remove from the environment".

4.3. Pre-service teachers' knowledge about the impacts of marine plastic pollution on natural systems

Responses to open-ended questions 10 to 14 provided insight into pre-service teachers' knowledge about the impacts of marine plastic pollution on natural systems (38% answered Q10-Q11, 31% answered Q12-Q13, 15% answered Q14). They identified a range of impacts such as:

- ingestion of plastic by marine organisms which affects their digestive system, causes poisoning, suffocation, internal injuries, and starvation;
- disruption of food chains leading to harmful health impacts to humans;
- animals getting entangled in plastic and becoming susceptible to predators;
- reduction in marine species diversity;

Table 3
Sub themes developed from codes with mutual thematic connection.

Sub themes	1	2	3	4	5	6
Q5 Attitudes N = 6 Justify your responses to statement Q4: We should be concerned about high levels of marine plastics pollution.	Increasing amount in ocean and beaches	Unnecessary use	Concerning threat to ecosystems	Water pollution	Microplastic enters food chain	Neg. impact on humans
Codes	1, 3	2	4, 5,6,7, 9	10	8, 11	12
Sub themes	7	8	9			
Q6 Knowledge N = 6 What is marine plastic pollution?	Plastic, plastic debris and microplastic in marine ecosystem	Negative impact to marine life and ocean	Human activity			
Codes	13, 14, 15, 19, 21	17, 18, 20	16			
Sub themes	10	11	12			
Q7 Knowledge N = 6 Where are marine plastics found?	Waterways and bodies	Oceans and beaches	In marine organisms and their prey			
Codes	22, 26	23, 24, 25, 29	27, 28, 30			
Sub themes	13	14	15	16	17	18
Q8 Knowledge N = 6 Describe two challenges associated with tackling marine plastic pollution	Cheap and widely used	Difficult to reduce consumption	Reduce production	Waste management not good enough, economic costs and lack of resources	Challenge to clean up microplastic	Neg. Impact on biodiversity and humans
Codes	31, 32, 33, 32, 34	36	39	37, 42	35, 40	33, 38
Sub themes	19	20	21	22		
Q9 Knowledge N = 4 What is the difference between marine plastic pollution that has been lying in nature for a long time, and newly produced plastic?	UV causes weathering and breaking down to microplastic	Chemicals release into the water	Toxic to marine life	Accumulation in environment		
Codes	43, 44, 45, 46, 49, 52	48, 51	53	47, 50		
Sub themes	23	24	25	26		
Q10 Impact N = 5 What are the consequences of marine plastic pollution on nature?	Ingesting and released toxins kill marine organism	Disrupt the food chain, ecosystem, and cause health issues	Animals entangled and susceptible to predators	Reducing fishing and tourism		
Codes	54, 55, 63	56, 59, 61	57, 58, 60	62		
Sub themes	27	28	29			
Q11 Impact N = 5 How can marine plastics affect biodiversity?	Reduce the diversity of marine species and destroy habitats	Marine species can adapt or perish	New conditions and food sources			
Codes	64, 65, 66, 67, 68, 69, 70, 71, 73, 74	72	75			
Sub themes	30					
Q12 Impact N = 4 How can marine plastics affect organisms?	Affect digestion systems, cause poisoning, suffocation, internal injuries, starvation					
Codes	76–86					
Sub themes		31				
Q13 Impacts N = 4 How can marine plastics affect ecosystems?		Alter food chain, habitats, and affect the global marine ecosystem				
Codes		87–93				
Sub themes	32	33	34			
Q14 Impacts N = 2 Do you know the challenges plastic in organisms can cause?	Consumed by humans	Neg. effect on peoples‘ health	Decreased tourism			
Codes	94, 95	98	96, 97			

- destruction of habitats is forcing marine species to either adapt or perish, as there may be new environmental conditions and food sources;
- marine plastic pollution will also affect and reduce fishing and decrease tourism.

The range of responses indicate a comprehensive understanding of the impacts of marine plastic on natural systems, although an anthropocentric viewpoint emerged through some of the responses: “It is toxic, can kill marine life, disrupt the food chain. This in turn can disrupt a whole eco-system reducing fishing (food) and tourism”.

Other responses showed some understanding of the concept of bioaccumulation in food chains: “Marine plastics can then breakdown into micro-plastics which can be digested by marine organisms. When these organisms are consumed by humans, we are essentially filling our bodies with plastic”.

Overall, the results of this study’s small sample of Australian pre-service teachers indicate that they are concerned about the impacts of marine plastic pollution. They believe that consumers and governments should take an active role in mitigating or overcoming marine plastic pollution, although they also acknowledge a range of challenges associated with tackling the issue. Results also indicate that in general, the sample of pre-service teachers in this study possess good knowledge about what constitutes marine plastic pollution and its impacts on natural and social systems.

5. Discussion

The discussion is presented based on the research question. For each aspect of the question (attitude and knowledge) we interpret the results in relation to contemporary literature, then focus on implications for preparing future teachers to address marine plastic pollution within their school communities.

5.1. Pre-service teachers' attitudes towards marine plastic pollution

Previous studies have found that young people and teachers' beliefs and attitude towards environmental issues are shaped by their personal experiences (Chareka, 2010; Connell et al., 1999; Esa, 2010; Ozsoy and Ahi, 2014; Pellier et al., 2014; Strife, 2012), region of residence (Chareka, 2010; Fleer, 2002; Holden, 2006; Ozsoy and Ahi, 2014; van Staden, 2006), gender (Chareka, 2010; Finnegan, 2023; Hicks, 1996; Hicks and Holden, 1995; Holden, 2006; Hutchinson, 1997; Naval and Repáraz, 2008), age (Eckerlsey, 1999; Finnegan, 2023; Fleer, 2002; Hicks, 1996; Ozsoy and Ahi, 2014; van Staden, 2006), and media (Connell et al., 1999; Holden, 2006; Pellier et al., 2014; Strife, 2012; Thompson et al., 2022). This research reinforces the significance of such influences. The formal and informal education that pre-service teacher participants gained through personal and school experiences may contribute to attitudes of concern about marine plastic pollution, particularly if they have observed the insidious impact of this issue over time.

Pre-service teachers' attitudes towards marine plastic pollution may also be shaped by age, gender, and the media. Most study participants in our sample (92%) were female and young – 21 years or below (75%). Research finds that young females and female pre-service teachers have more positive environmental attitudes and tend to become more involved in pro-environmental actions compared to males (Gan et al., 2022; Tuncher et al., 2009). Further, media reports on the deterioration of World Heritage sites, especially the GBR, are copious, particularly in local news. We presume, therefore, that to some extent age, gender and the media are likely to have influenced the findings of this study. Testing of such factors, however, was beyond the scope of this study, hence, we are not able to make any definitive comments on the influence of age, gender, or media on pre-service teachers' attitudes to marine plastic pollution at this time.

In this study, some of the items in the attitude section of the questionnaire probed pre-service teachers' ideas about behavior with respect to plastic use, although these were couched in general terms rather than specifically targeting individual behavior. Therefore, some tentative conclusions can be made based on their responses to these items. The participants may be willing to reduce their plastic consumption and support governments spending money to clean up marine plastics. The findings also show that all pre-service teachers agreed that consumers must demand less plastic to reduce plastic production and 91% agreed that the government should increase efforts to clean up marine plastics, even if it means spending more money.

Last, it is important to recognize that the above influences and plastic related behaviors are not mutually exclusive and are, therefore, likely to interact. Further studies are necessary to differentiate exactly how diverse experiences affect pre-service teachers' attitudes towards marine plastic pollution. Developing a deeper, more nuanced understanding of influences on pre-service teachers' attitudes will help the development of more effective environmental education programmes.

5.2. Pre-service teachers' knowledge about marine plastic pollution

The findings also showed that, in general, pre-service teachers possess good knowledge of what constitutes marine plastic pollution. As discussed earlier, the pre-service teachers in our sample receive instruction on marine plastic pollution during their first year of study, particularly in relation to the GBR. This topic explores the issues that impact the long-term sustainability of the GBR including its significance and the threats it faces such as declining water quality and marine debris, especially plastic pollution. Instruction during the first year could contribute to pre-service teachers' good levels of knowledge about marine plastic pollution. Notable, however, is that knowledge about environmental issues does not necessarily lead to positive change in environmental behavior (Gifford and Nilsson, 2014; Schultz et al., 2013), which is what educators aim to achieve. While knowledge is a necessary pre-condition to positive environmental behavior, on its own it provides insufficient stimulus (Gifford and Nilsson, 2014). This assertion is supported in Gan et al.'s (2022) study that found Chinese university students who had a good understanding of marine pollution did not necessarily exhibit positive behaviors towards the marine environment. According to Charitou et al. (2021) environmental behaviors are affected by a range of variables, including the additional effort required, lack of time and money. Note that this study did not test links between knowledge and positive actions to ameliorate marine plastic pollution. Hence, we are not able to provide any decisive conclusions. However, it seems reasonable to suggest there may be a range of factors that influence whether pre-service teachers with good knowledge about marine plastic pollution adopt positive actions. At this stage, this provides an area for further study.

Digging deeper into the results of pre-service teacher participants' knowledge about marine plastic pollution exposed that some pre-service teachers have limited knowledge and hold misconceptions related to the scientific concepts underpinning marine plastic pollution. This is evident in the three responses to question 14 (plastics can be taken up in the food chain. Do you know the challenges plastic in organisms can cause?) that were either off-topic or demonstrated a basic understanding of bioaccumulation. For example, one response explained that when humans consume marine organisms, humans are filling their bodies with plastic. A knowledgeable response to such a question might have included information about the release of toxic chemicals and elements which can lead to bioaccumulation.

6. Conclusion

This study investigated pre-service teachers' attitudes to and knowledge of marine plastic pollution and its impacts on natural environments. Based on our findings, pre-service teachers' attitudes to marine plastic pollution were shaped by a range of variables, pre-service teachers demonstrated good knowledge of what constitutes marine plastic pollution, and they were also concerned about the impacts of marine plastic pollution. The participants provided a range of reasons for why we should be concerned about marine plastic pollution, emphasising its impact on the natural environment, at a local and global level. Their responses indicated that they also possessed a comprehensive understanding of what these impacts included. We found that the participants were well informed about what constituted marine plastic pollution and of the challenges associated with tackling this issue. These findings could be reflective of the participants' personal experiences of the impact of marine plastic pollution on the GBR.

Finally, we discuss the implications, limitations and future research directions stemming from this study. The implications of the findings are presented as a preliminary pedagogical framework for the teaching and learning of marine plastic education in initial teacher education. The paper concludes by acknowledging the study's limitations and outlining future research directions.

6.1. Marine plastic pollution: A preliminary pedagogical framework

Given that teachers play an important role in shaping the knowledge and attitudes of their own students, we believe there is merit in developing resources to equip pre-service teachers with the necessary background to teach their own students, once in schools. To this end, we propose a preliminary pedagogical framework (Fig. 1) that draws on pedagogical content knowledge (PCK) (Shulman, 1986) to cover required content knowledge, and pedagogical strategies for the teaching and learning of marine plastic pollution. Content knowledge includes pre-service teachers' understanding of what marine plastic is, what the impacts of marine plastic pollution are, and the science underpinning marine plastic pollution. The development of specialized scientific knowledge on the issue of marine plastic pollution is essential for pre-service teachers to be able to teach the material in a confident and

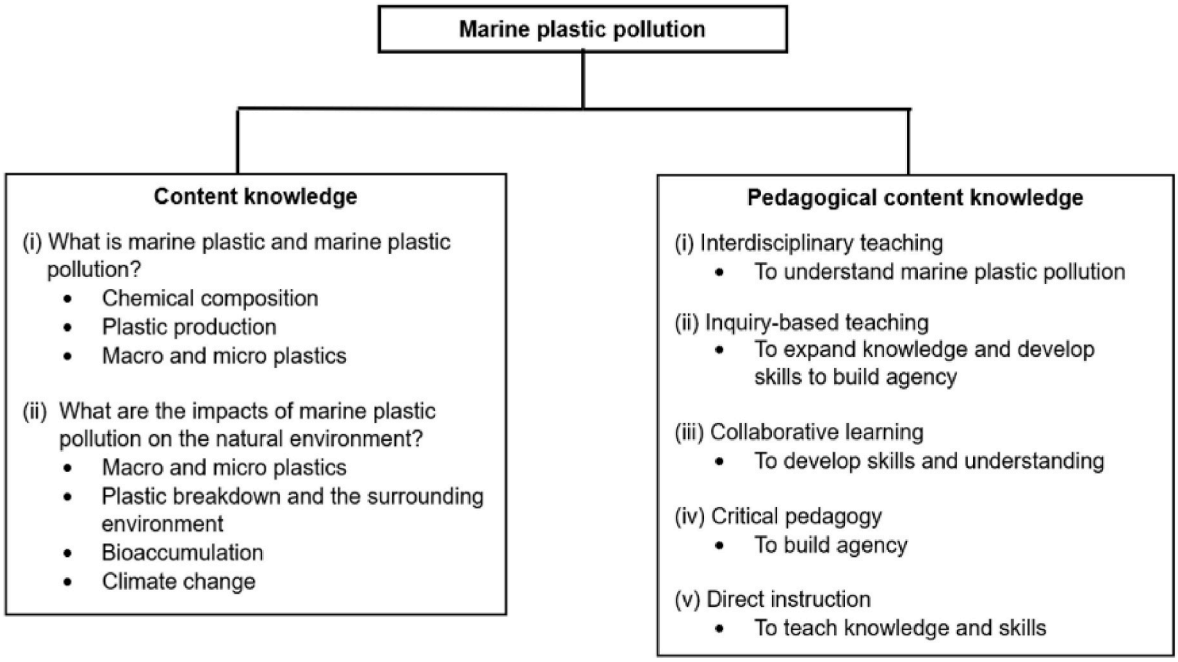

Fig. 1. Marine plastic pollution: a preliminary pedagogical framework.

engaging manner. Many early childhood and primary pre-service teachers in Australia suffer from low confidence and negative experiences in relation to science education (Herbert and Hobbs, 2018), resulting in a lack of confidence to teach science successfully (Tytler, 2007). Therefore, a teaching resource for marine plastic pollution education, including the essential science concepts, aims to prepare pre-service teachers to deliver this content effectively.

Pedagogical content knowledge refers to the subject matter knowledge for teaching relative to a learning area (Shulman, 1986). It is a type of knowledge which integrates the content knowledge of a specific learning area and the pedagogical knowledge for teaching that particular learning area (OECD, n.d.). Fig. 1 reflects that in the case of marine plastic pollution, pedagogical knowledge includes (i) interdisciplinary teaching (to understand marine plastic pollution from different disciplinary perspectives), (ii) inquiry-based teaching (to expand knowledge and developing skills to build agency), (iii) collaborative learning (to develop skills and understanding), (iv) critical pedagogy (to building agency), and (v) direct instruction (to teach knowledge and skills). Having this type of knowledge is important for engaging students and building capacity and action competence (Jensen, 1997) for overcoming what is a critical global sustainability issue with compounding effects.

It should be noted, given the small sample of pre-service teachers involved in this study, that this is a preliminary framework which is not absolute or definitive. Rather, the framework is meant to provide a starting point for developing a resource for teachers wishing to teach marine plastic pollution. This study is a first step towards investigating pre-service teachers' knowledge and attitudes towards marine plastic pollution. It is expected that this preliminary framework can and should be further augmented through either a large-scale quantitative study on teachers' knowledge and attitudes to this important issue, or an experimental study investigating the implementation of such knowledge into teaching and learning.

6.2. Limitations and future research directions

It is also important to outline the limitations of this study. As mentioned earlier, the number of pre-service teachers who took part in this study was small. Therefore, it is difficult to make general or definitive statements about the knowledge and attitudes of pre-service teachers towards marine plastic pollution. However, the findings provide some rich insight, particularly given the context of this study in remote Far North Queensland and the proximity to the GBR. It would be useful to replicate this study with more participants, perhaps also from a different context. Future plans include repeating this study with Norwegian pre-service teachers which would provide a basis for some valuable comparisons.

CRediT authorship contribution statement

Hilde Ervik: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Neus (Snowy) Evans:** Writing – review & editing, Validation, Conceptualization. **Subhashni Taylor:** Writing – review & editing, Validation, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.143950.

Data availability

Data will be made available on request.

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